Recent DIS Results from Jefferson Lab: A_1^n at High x and the Q^2-dependence of g_2^n

T. D. Averett
(On behalf of the Jefferson Lab Hall A and Polarized ^{3}He Collaborations)

College of William and Mary, Williamsburg, VA 23187 USA

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In this talk, results were presented from two recently published Jefferson Lab experiments where longitudinally polarized electrons were scattered from a polarized ^{3}He target in the inclusive reaction $^3\vec{\mathrm{He}}(\vec{e},e')$ in the deep-inelastic region. Incident electrons with energies $E = 3.5-5.7$ GeV were scattered from polarized ^{3}He nuclei whose spins could be oriented parallel or perpendicular to the incident electron momentum, in the scattering plane of the electron. The helicities of the incident electrons were flipped pseudo-randomly at a rate of 30 Hz to minimize helicity correlated systematic uncertainties. A feedback system was also used to keep the helicity-dependent beam charge asymmetry below 50×10^{-6} for a typical run in the g_2 measurement. Scattered electrons were detected in either one of two nearly identical spectrometers. The detector package included vertical drift chambers for particle tracking, two segmented scintillator trigger planes, and used a gas Cherenkov detector and lead-glass calorimeter for particle identification. Electron polarization was measured periodically using a Møller polarimeter and monitored continuously using a Compton polarimeter.

To study polarized neutrons, a target containing ^{3}He nuclei was polarized using spin-exchange optical pumping. The ^{3}He ground state is dominated by the S-state in which the two proton spins are anti-aligned and the spin of the nucleus is carried entirely by the neutron. To obtain neutron information, a correction based on the ^{3}He wavefunction was applied to the measured ^{3}He data. The ^{3}He was contained in a sealed, two-chambered, aluminosilicate glass cell, along with a small quantity of N_2 and Rb to aid in the polarization process. Polarized ^{3}He is produced in the spherical upper chamber by first polarizing Rb atoms with optical pumping. These atoms can transfer their spin to the ^{3}He nucleus during binary collisions. Incident electrons scatter from the polarized ^{3}He in the cylindrical lower chamber which is 40 cm long with side walls of thickness ≈ 1.0 mm and end windows of thickness ≈ 130 μm. The ^{3}He density as seen by the beam is 2.9×10^{20}/cm^3. The average in-beam target polarization was $P_t = (40.0\pm1.4)\%$ as measured using both nuclear magnetic resonance and electron paramagnetic resonance.

In the first experiment [1], the virtual photon asymmetry A_1^n for the neutron was measured in the high-x region at three values of $x = 0.33, 0.47, 0.60$ with corresponding $Q^2 = 2.7, 3.5, 4.8\ \mathrm{GeV}^2$, where the structure of the nucleon is expected to be dominated by the valence quark structure. Though most realistic models of the nucleon predict a positive value for A_1^n, with an increase towards one as $x\to1$, prior neutron data at low

x are clearly negative. Existing data at high x have a large statistical uncertainty and are consistent with zero. The new precision data from Jefferson Lab show, for the first time, a positive slope and zero-crossing with increasing x as shown in Figure 1 Also shown

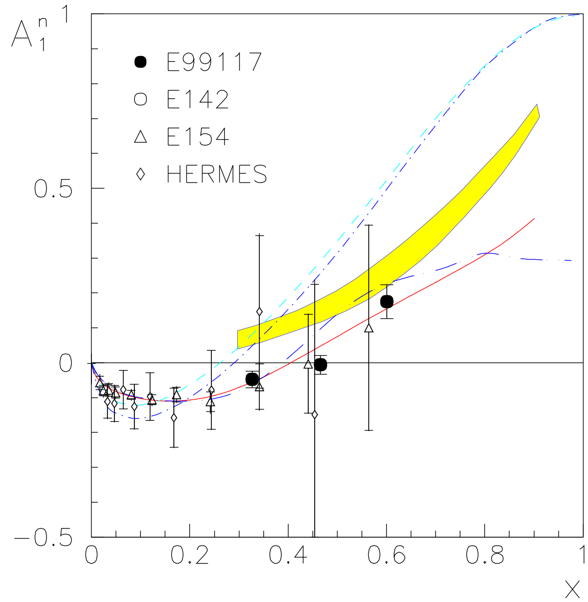

FIGURE 1. The solid circles show the new data for A_1^n from Jefferson Lab, along with world data and various theoretical predictions. The uncertainties are statistical. The two upper curves are pQCD models assuming hadron helicity conservation. The lower solid curve is a QCD-based NLO fit to world data and the lower dashed curve is a statistical model. The band is a relativistic constituent quark model.

in Figure 1 are various theoretical predictions for the x-dependence of A_1^n. The data are most consistent with models which do not require hadron helicity conservation (solid band and two lower curves), implying that quark orbital angular momentum is non-zero. Perturbative QCD models which require hadron helicity conservation (two upper curves) are consistently larger than the measured data.

In the second experiment [2], the neutron spin structure g_2^n was measured at fixed $x \sim 0.2$ at five values of Q^2 in the range $0.57 - 1.34$ GeV^2. Unlike the well-known g_1 spin structure function, g_2 cannot be interpreted using simple quark-parton models. It contains higher-twist contributions (e.g. quark-gluon correlations, quark-mass effects) that enter at the same order in Q^2 as the leading-twist contributions arising from scattering from asymptotically-free quarks, it must be interpreted using a framework such as the Operator Product Expansion (OPE). This is a model-independent approach based directly on QCD where the unknown hadronic currents relevant for polarized DIS are expanded in terms of quark and gluon operators. Because both g_1 and g_2 contain the same twist-2 operator corresponding to scattering from a massless, non-interacting quark, the Wandzura-Wilczek relation can be used to express the twist-2 contribution to g_2 in terms of g_1 as,

$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 \frac{g_1(y,Q^2)}{y} dy. \tag{1}$$

By making precise measurements of g_2^n and subtracting g_2^{WW}, calculated using precise g_1^n data, one is left with a quantitative measure of the higher-twist contributions to the structure of the nucleon. Measurements of g_2 are particularly interesting because they provide clean, model-independent information on the structure of the nucleon beyond simple, non-interacting quark models. The simplest higher-twist term in the OPE corresponds to scattering from a quark which is at the same time exchanging a gluon with the rest of the nucleon. Because these quark-gluon correlations are responsible for quark confinement, higher-twist effects must be included in any realistic model of the nucleon.

Data from this experiment are shown in Figure 2 along with model predictions (dashed and dotted curves) and calculations of g_2^{WW} (solid curves). The measured data show a positive deviation from the g_2^{WW} prediction at lower Q^2, indicating that contributions such as quark-gluon interactions may be important.

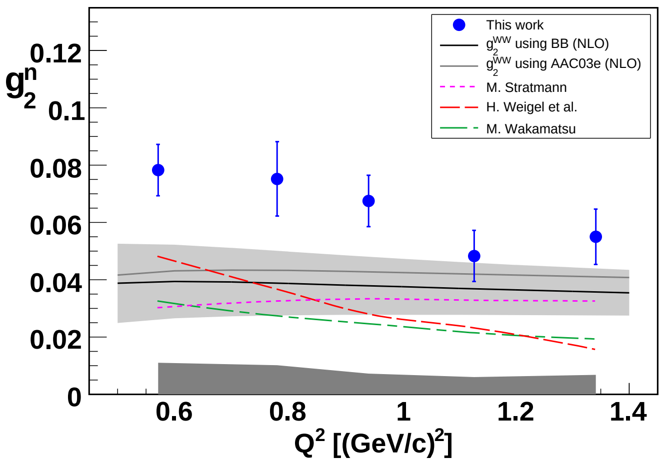

FIGURE 2. Results for g_2^n as a function of Q^2 are shown along with model calculations (dashed and dotted curves). Data are shown with statistical uncertainties only, with the systematic uncertainties indicated by the lower, dark gray band. The dark solid line, with gray uncertainty band, and the light gray line are calculations of g_2^{WW} using NLO fits to world g_1^n data, evolved to our measured Q^2.

In summary, new precision results from Jefferson Lab using polarized inclusive deep-inelastic scattering were presented. Results for A_1^n in the high-x region show, for the first time, a clear zero-crossing and positive slope as $x \to 1$. The data are consistent with models which do not require hadron helicity conservation, indicating that quark orbital angular momentum may play an important role in the valence quark region. New results for the Q^2-dependence of g_2^n show a two order of magnitude improvement over previous world data. These results are consistently above the twist-2 g_2^{WW} prediction at low Q^2, indicating the possible presence of quark-gluon correlations. For further information regarding these measurements and associated theoretical calculations, see Refs. [1] and [2], and references therein. For further information on the Jefferson Lab Hall A instrumentation and detector systems, see Ref. [3].

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